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**Selective optical doping to predict the performance  
and reveal the origin of photocurrent peaks  
in  
quantum dots-in-a-well infrared photodetectors**

**by**

**Linda Höglund**

Q. Wang, S. Almqvist, E. Petrini, J.Y. Andersson  
Imagic, Acreo AB, Sweden

C. Asplund, H. Malm  
IRnova, Sweden

P.O. Holtz, Linköping University, Sweden

H. Pettersson, Halmstad University and Lund University, Sweden

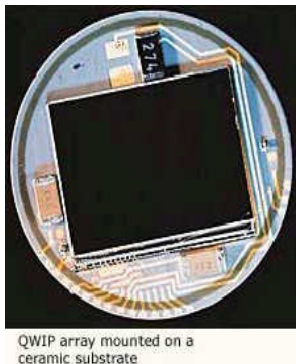
# Outline

1. Motivation and background
2. Optical pumping as artificial doping
3. Optical characterisation to reveal interband transitions
4. Origin of photocurrent peaks
5. Predicted performance
6. Summary

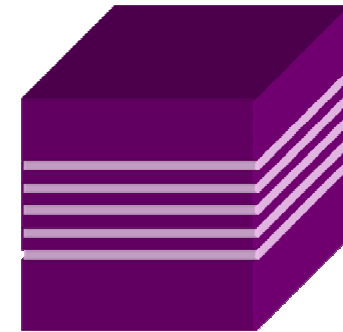
# Motivation and background



Acreo / IRnova manufactures IR detectors based on quantum wells

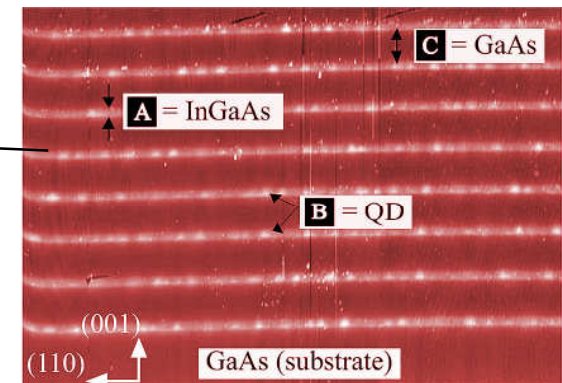
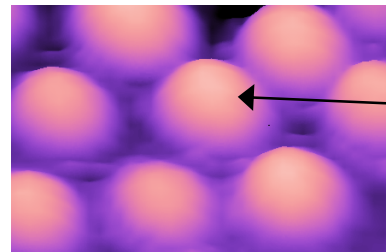


Quantum wells



Quantum dots-in-a-well structure

Further development  
through replacement of  
quantum wells  
↓  
quantum dots

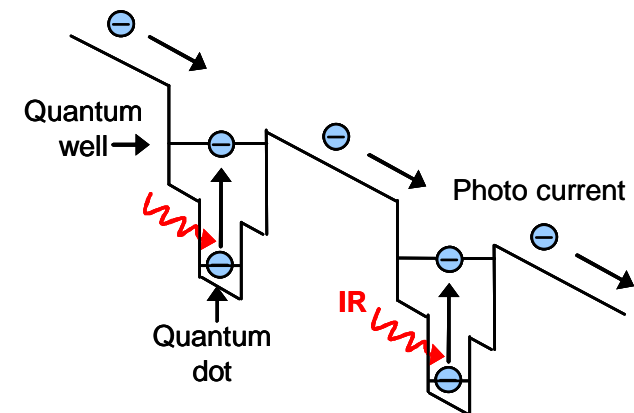
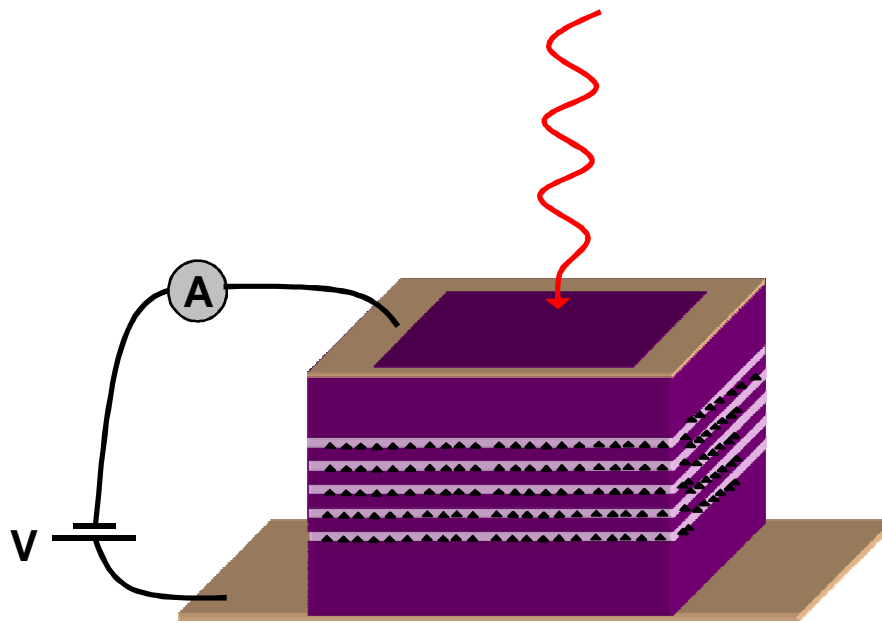


# Quantum Dots-in-a-well

## Infrared Photodetectors



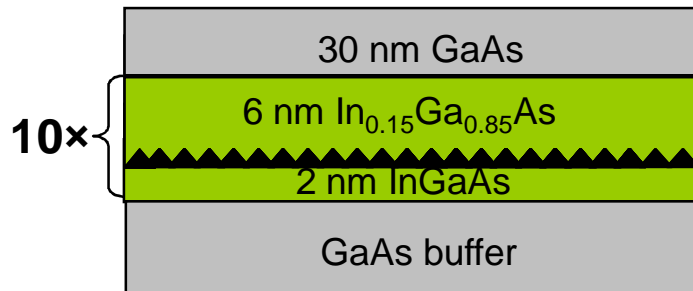
The detection wavelength is partly determined by the dot and partly by the well -> more freedom in the design of the structure.



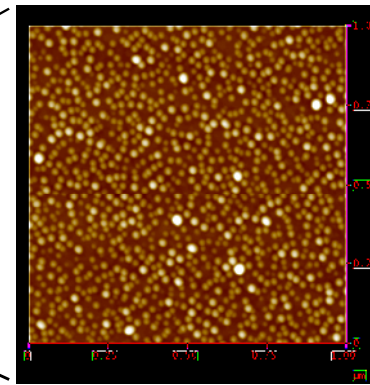
# Structures and components in this study



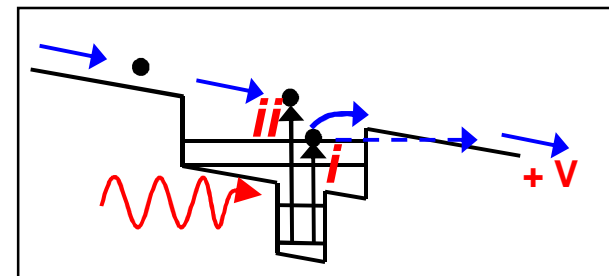
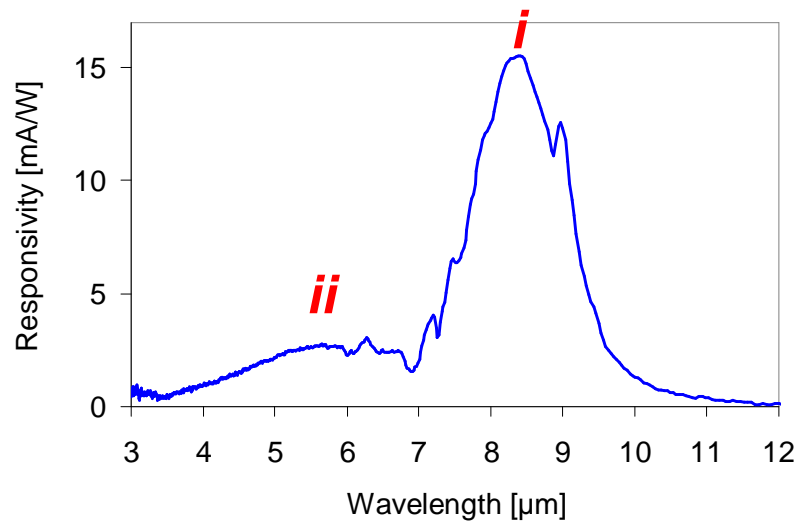
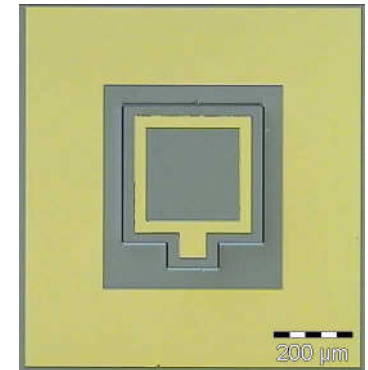
## Dots-in-well structure



dot density  $\sim 1\text{E}11\text{cm}^{-2}$



170  $\mu\text{m}$  x 170  $\mu\text{m}$   
single pixel components



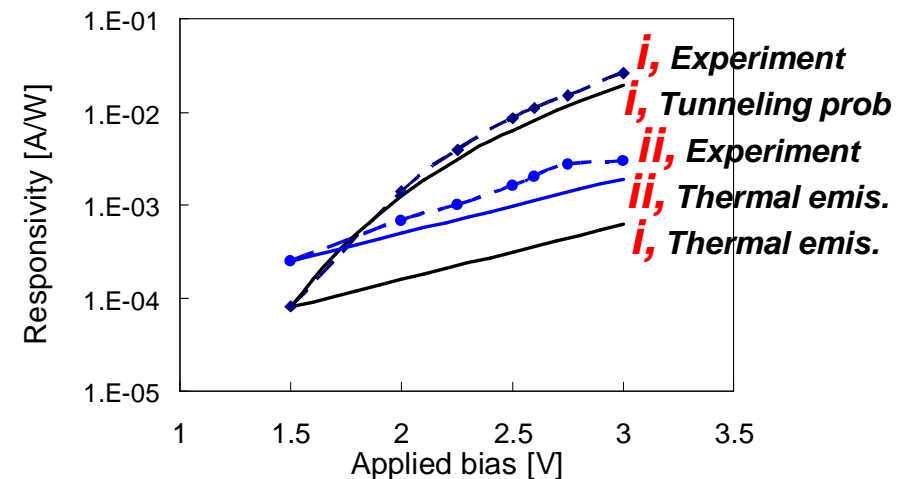
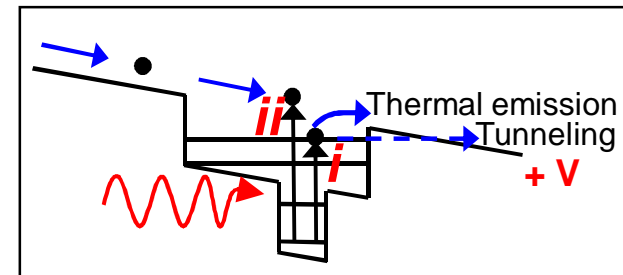
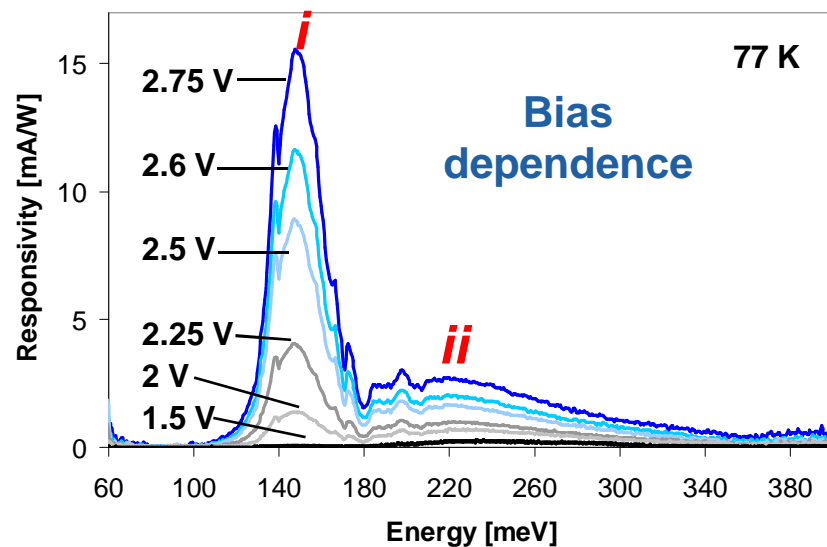
# Bias dependence of the photocurrent



Appl. Phys. Lett. **93**, 103501 (2008)

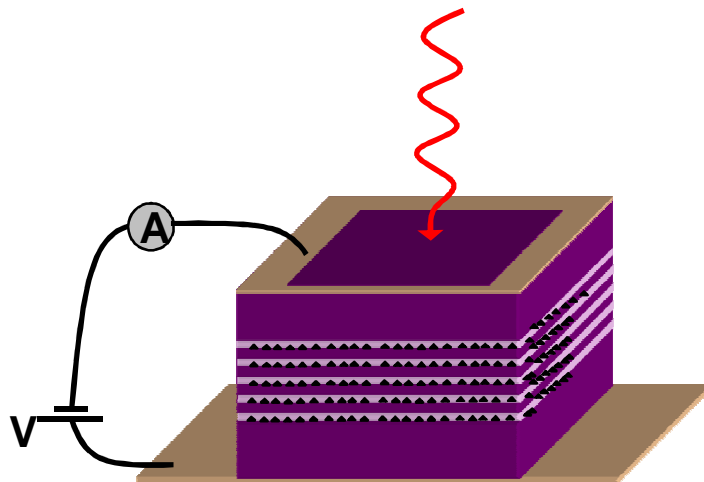
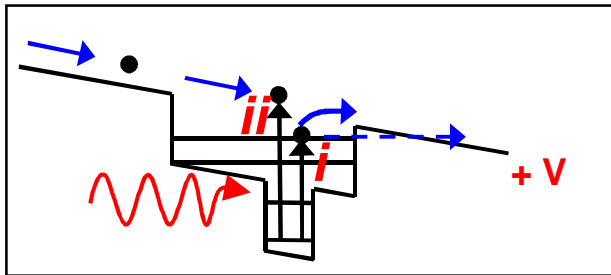
Responsivity limited by:

- tunneling
- lack of doping of the QDs

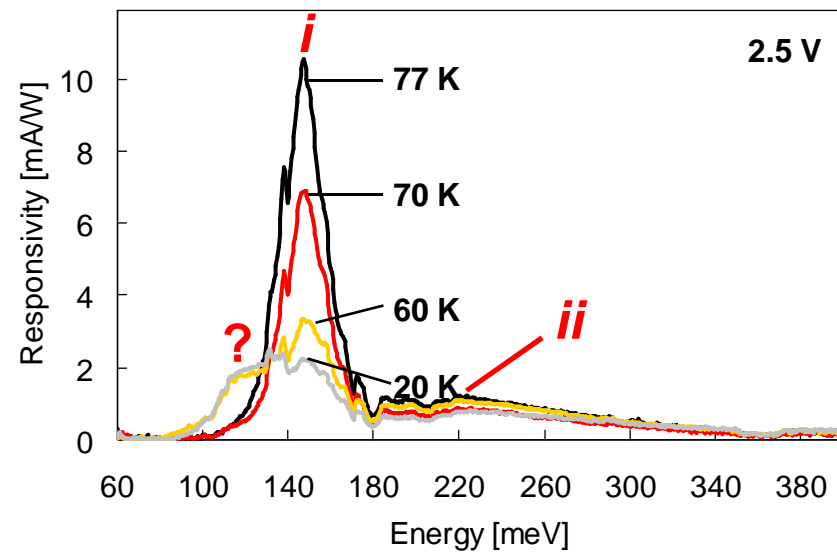


**How much can the responsivity be increased?**

# Temperature dependence of the photocurrent

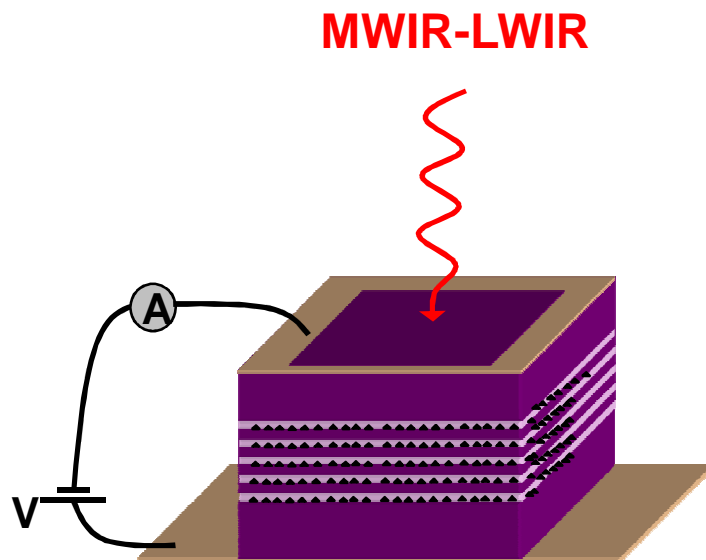


## Temperature dependence



**What is the origin of the 120 meV peak?**

# Optical pumping as artificial doping



**How much can the responsivity be increased?**

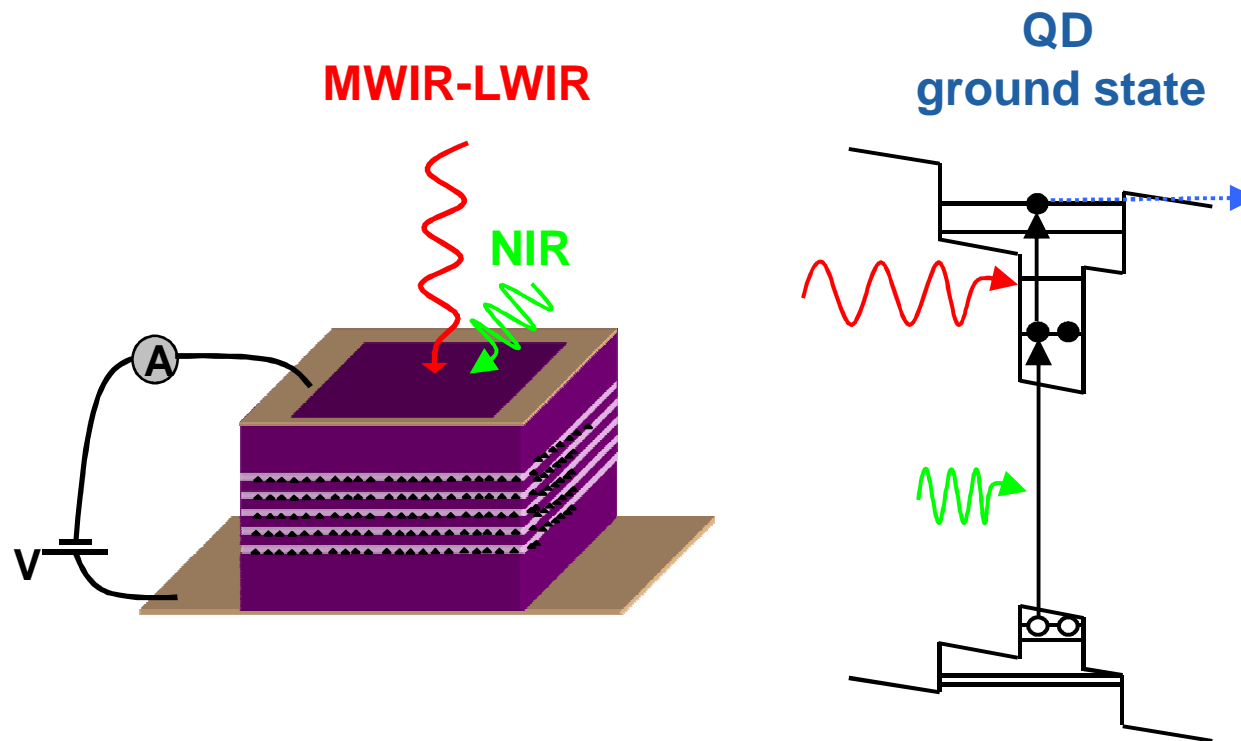
**What is the origin of the 120 meV peak?**



# Optical pumping as artificial doping



Selective filling of:



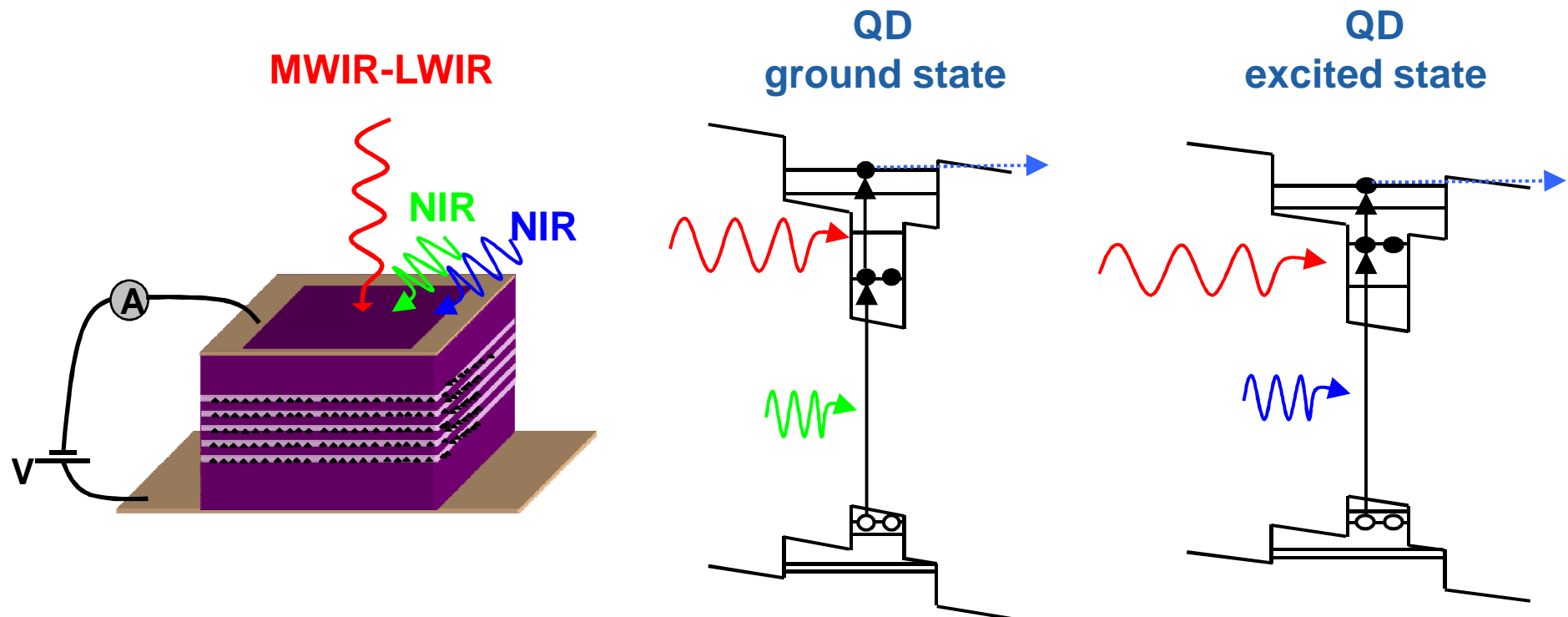
How much can the responsivity be increased?

What is the origin of the 120 meV peak?

# Optical pumping as artificial doping



Selective filling of:



How much can the responsivity be increased?

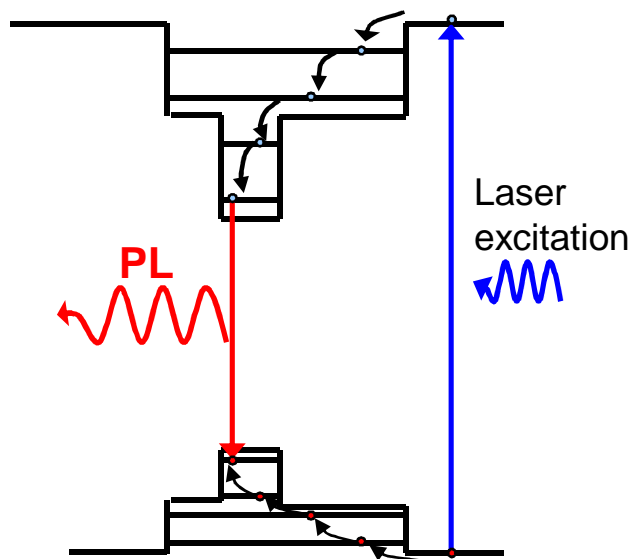
What is the origin of the 120 meV peak?

# Optical characterisation of the DWELL material

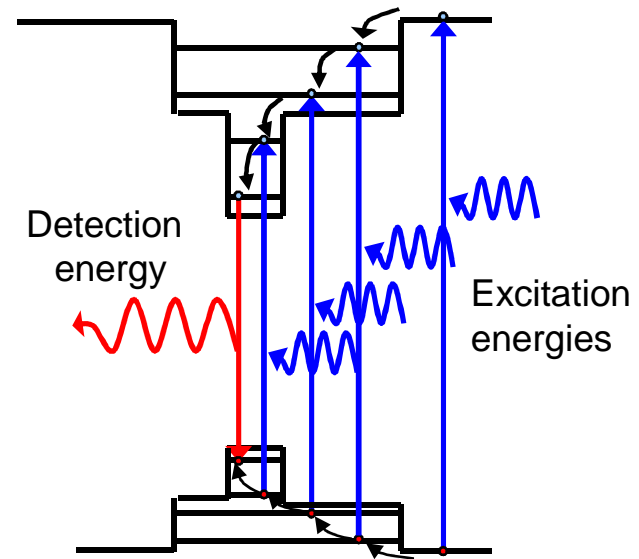


The interband transitions of interest were revealed using:

## Photoluminescence (PL)



## PL excitation (PLE)

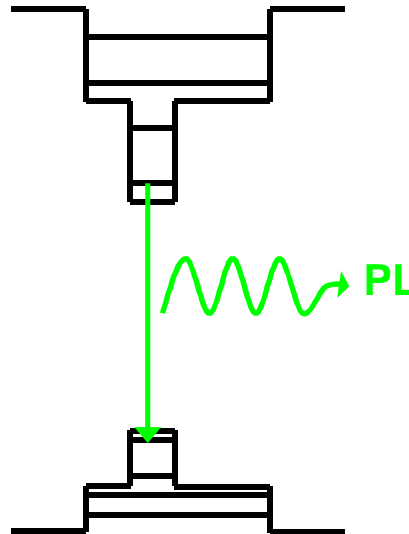
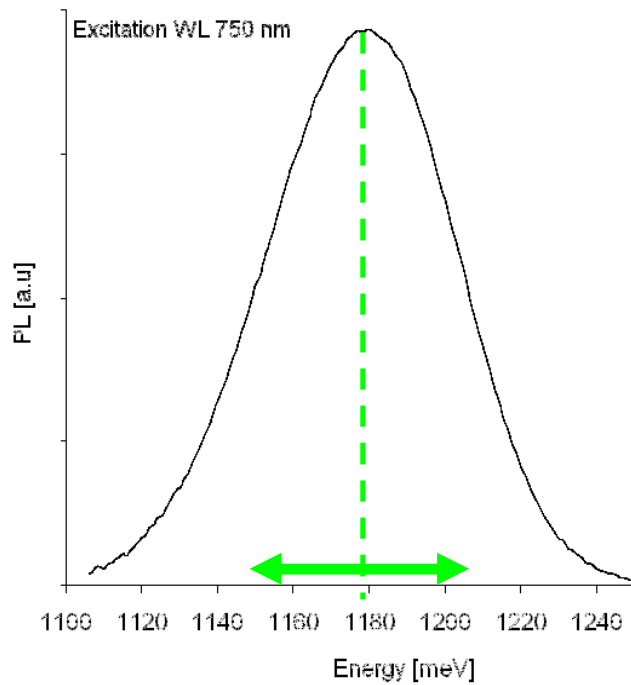


# Optical characterisation of the DWELL material



## Photoluminescence (PL)

-> ground state transition energies



# Optical characterisation of the DWELL material

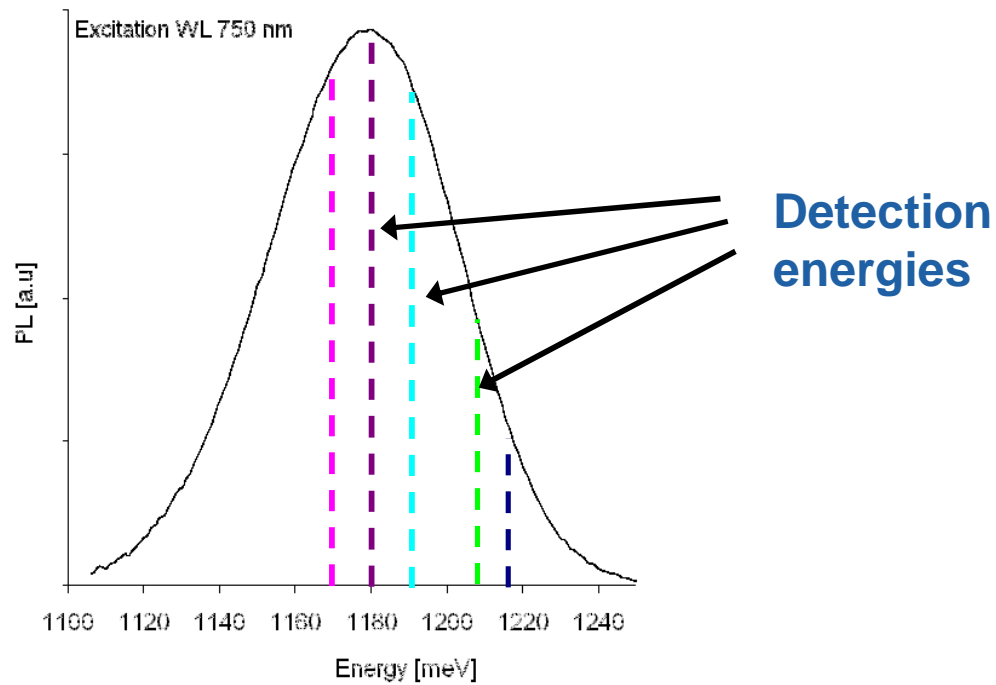


## Photoluminescence (PL)

-> ground state transition energies

## PL excitation (PLE)

-> excited state transition energies

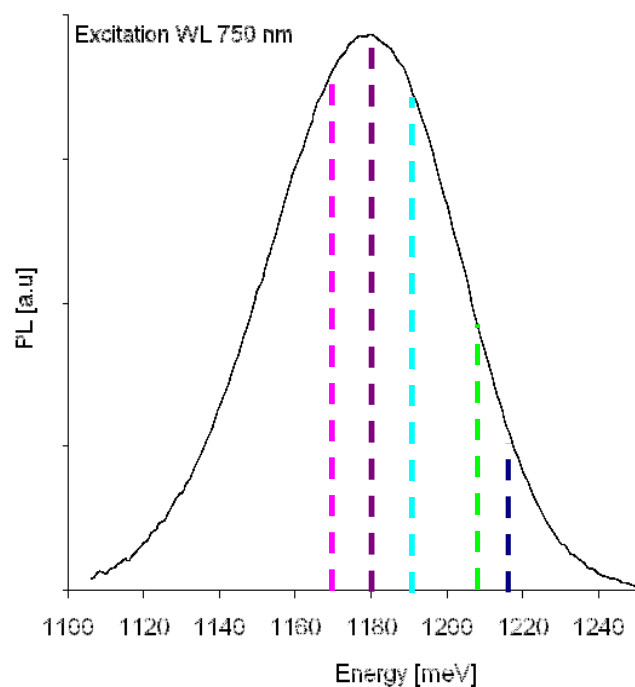


# Optical characterisation of the DWELL material



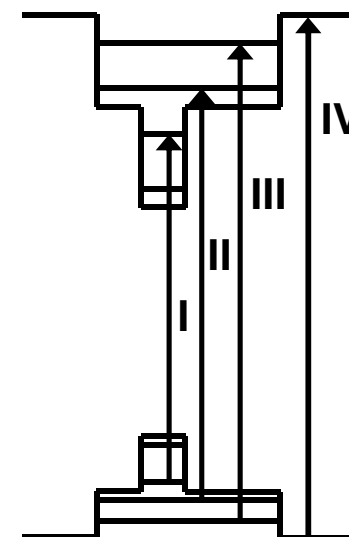
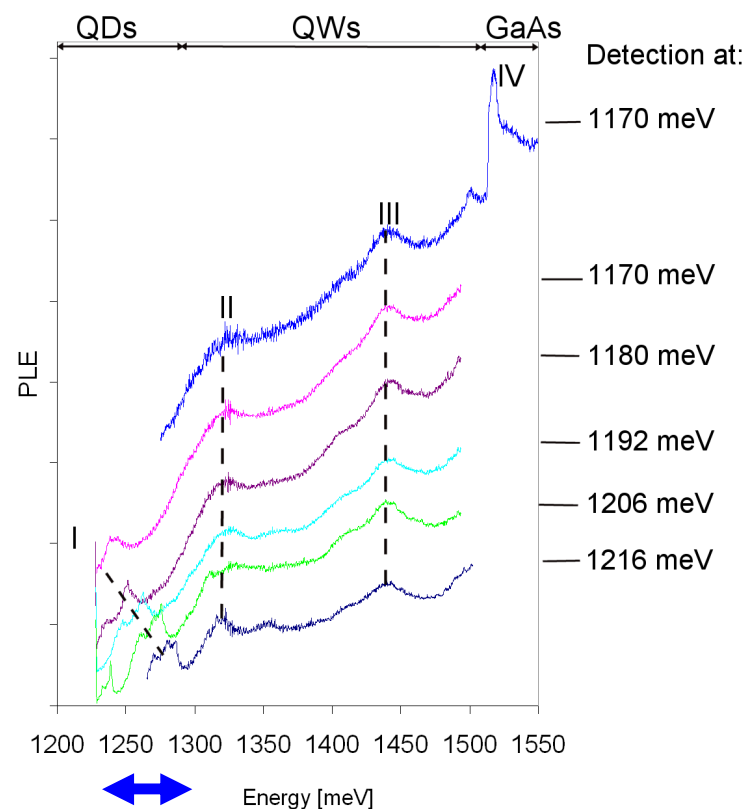
## Photoluminescence (PL)

-> ground state transition energies



## PL excitation (PLE)

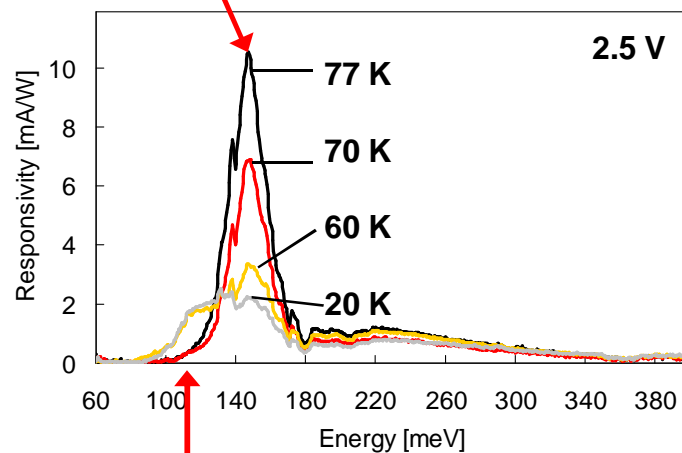
-> excited state transition energies



# Optical pumping to identify photocurrent peaks and predict the performance

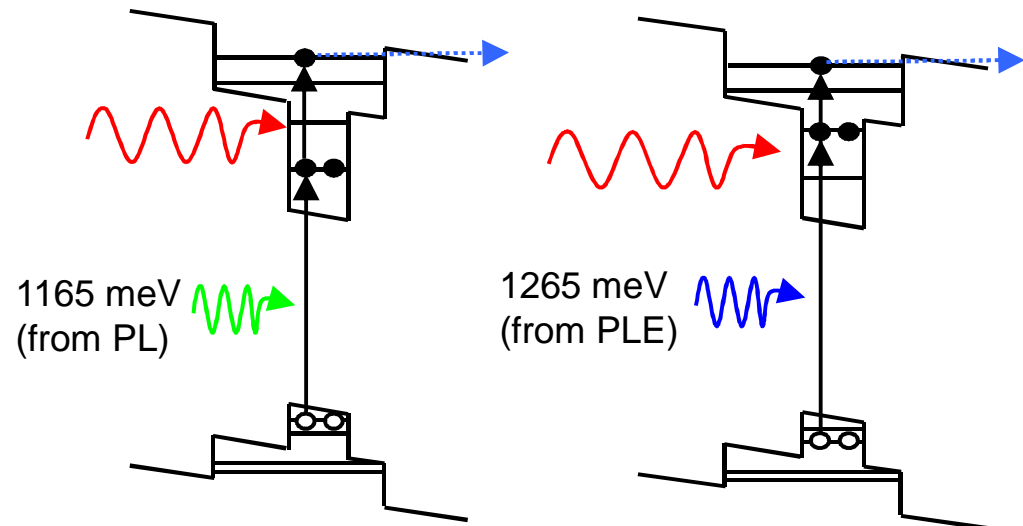


**Max. response?**



**Origin of low-T peak?**

**Optical pumping technique**  
→ selective filling of energy levels

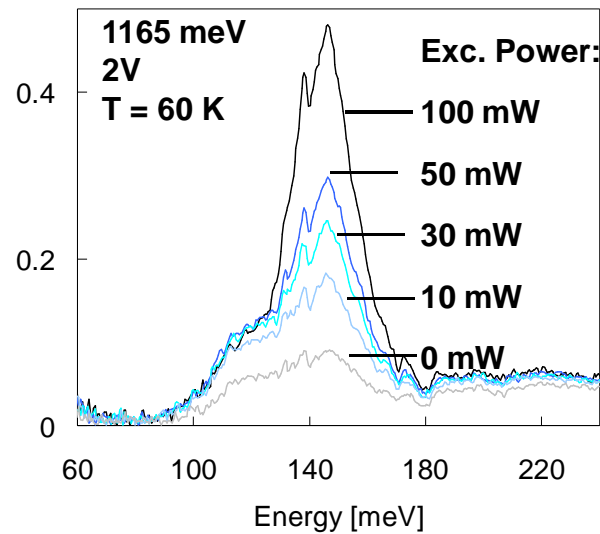
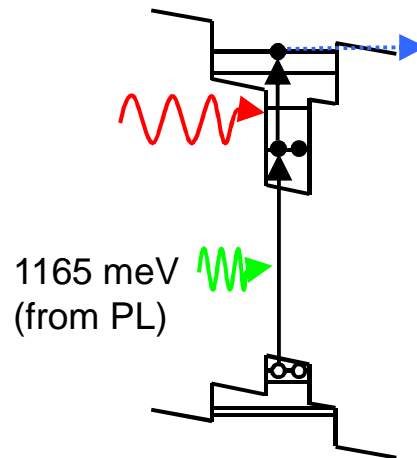
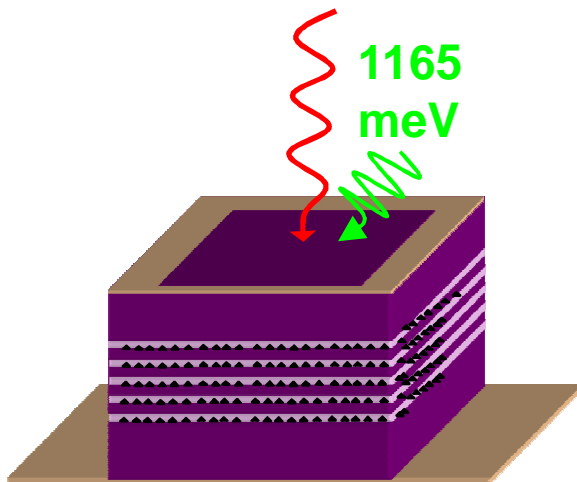


# Optical pumping to identify photocurrent peaks



Origin of  
low-T peak?

MWIR-LWIR



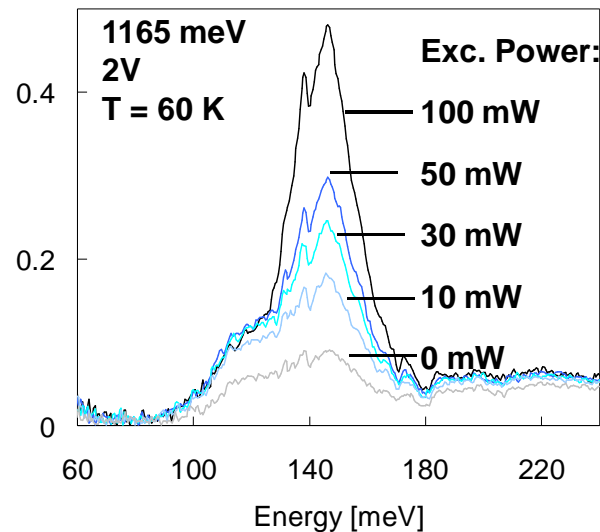
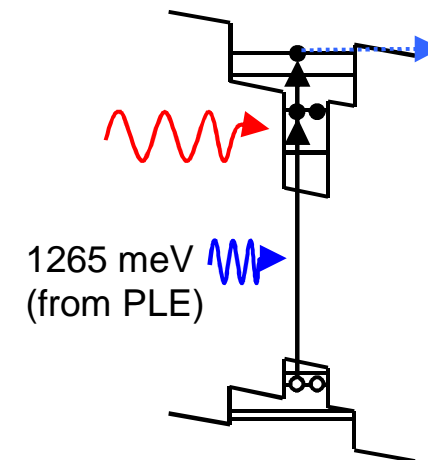
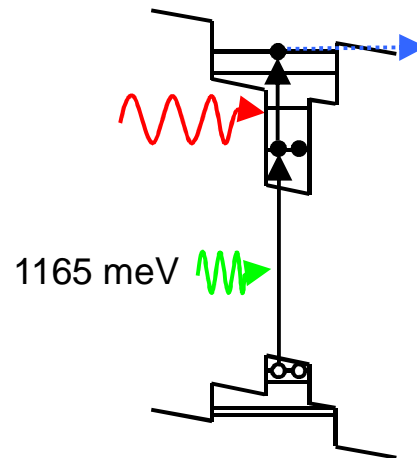
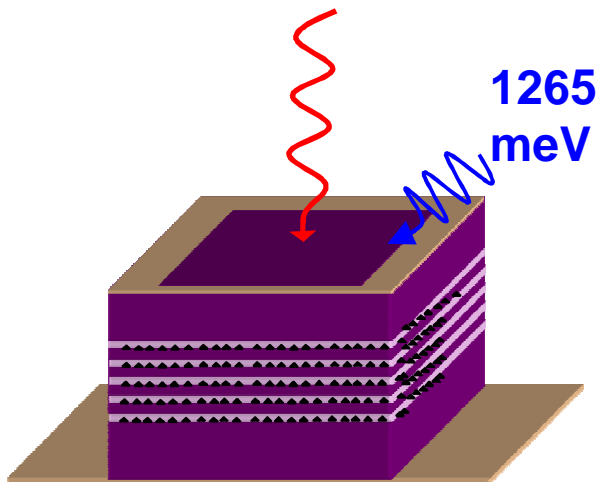


# Optical pumping to identify photocurrent peaks



Origin of  
low-T peak?

MWIR-LWIR

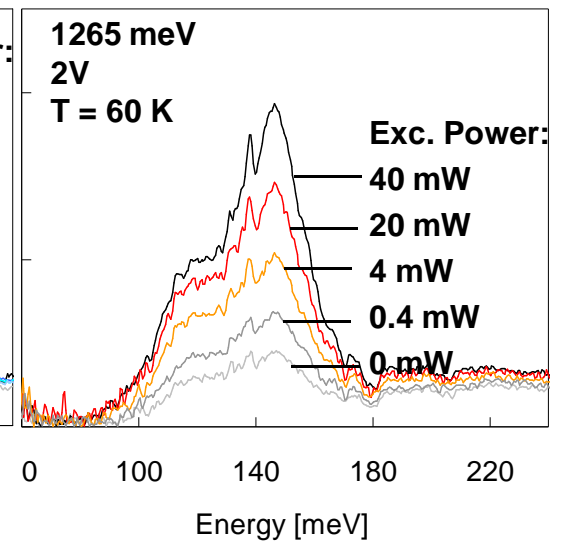
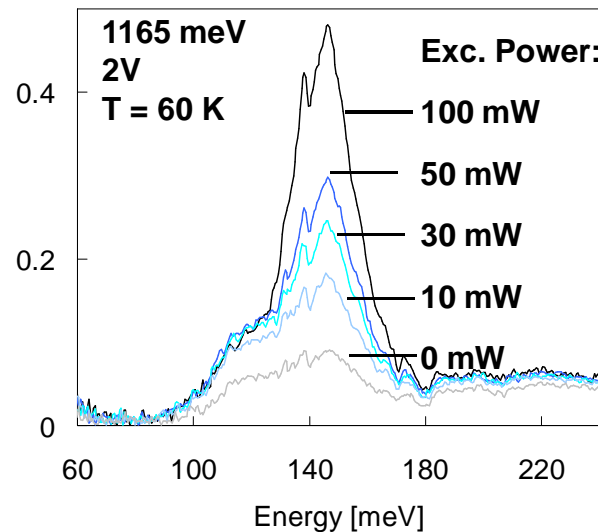
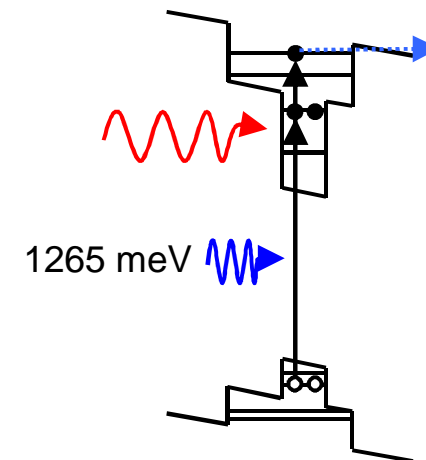
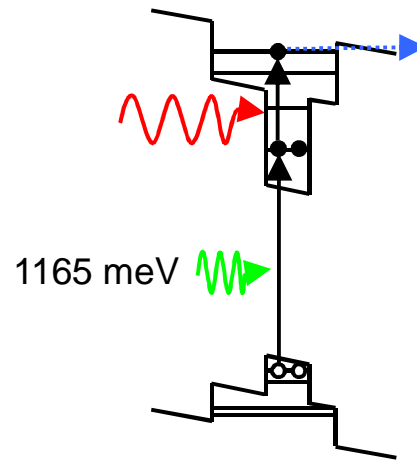
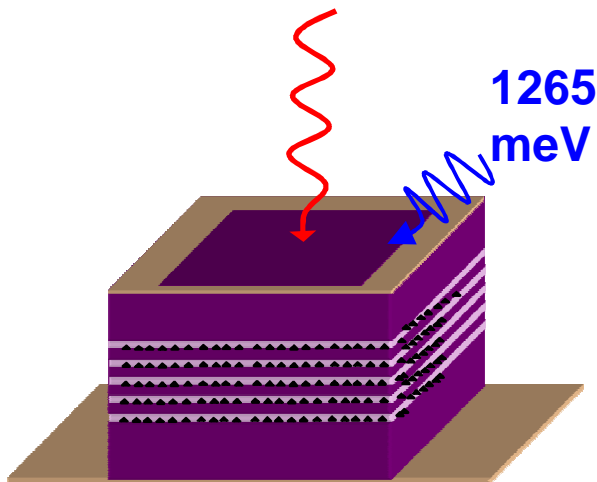


# Optical pumping to identify photocurrent peaks



Origin of  
low-T peak?

MWIR-LWIR

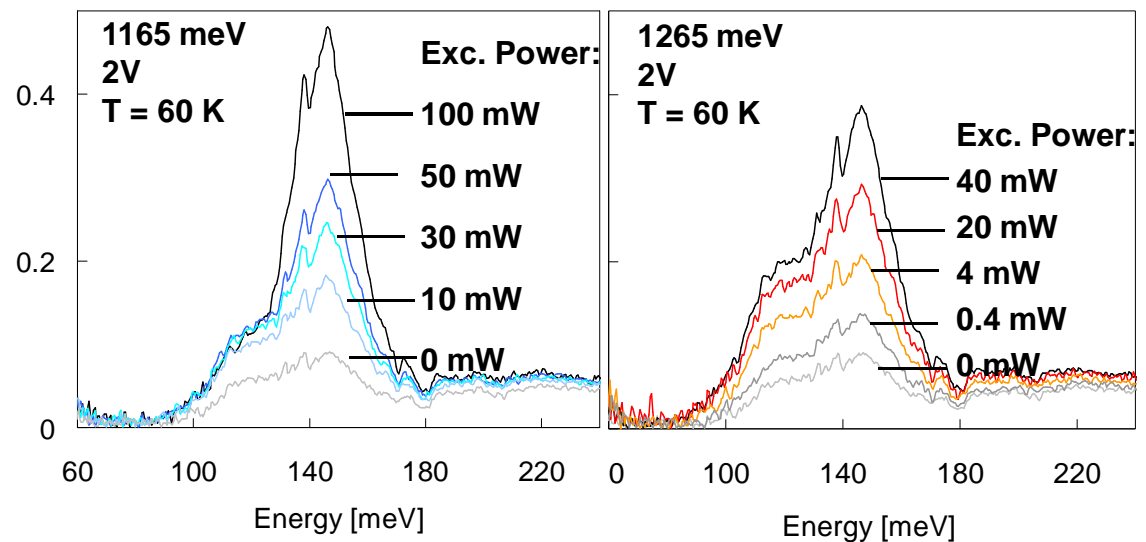
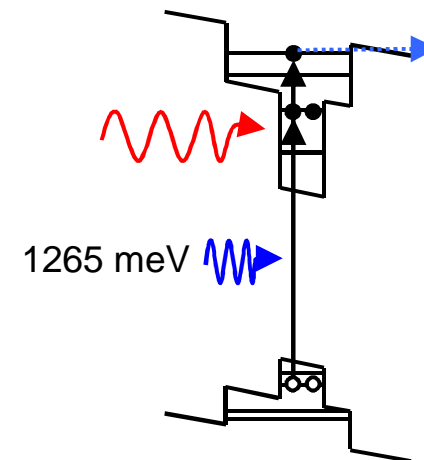
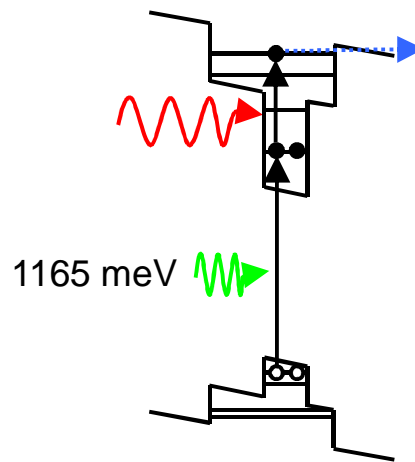
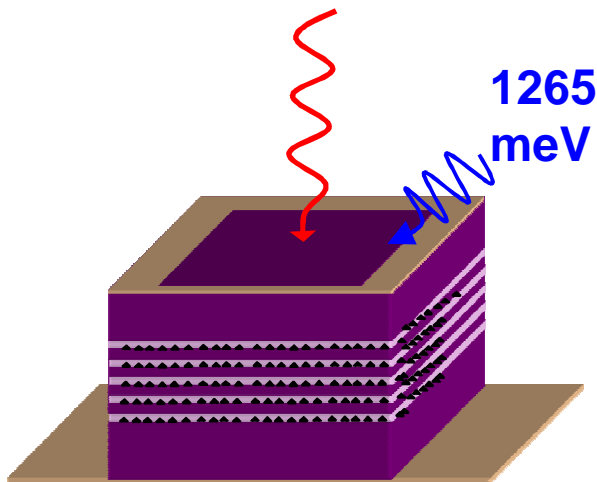


# Optical pumping to identify photocurrent peaks



**Origin of  
low-T peak?**  
Transition from  
QD excited state!

**MWIR-LWIR**

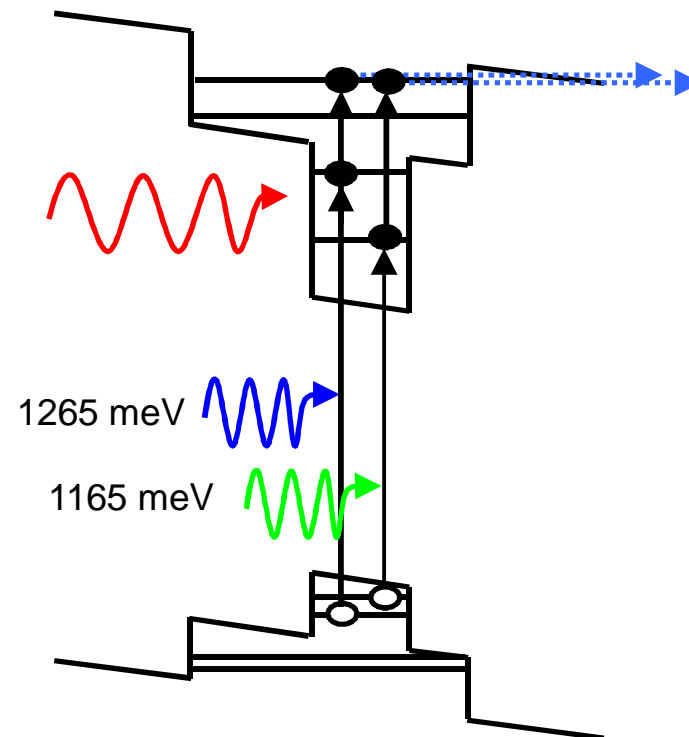
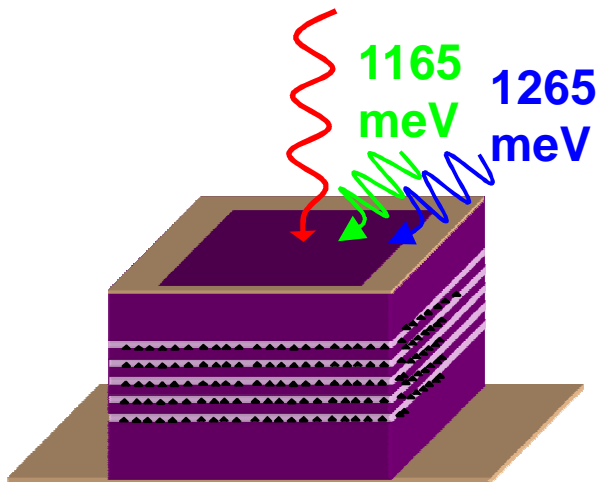


# Optical pumping to predict the performance



Max. response?

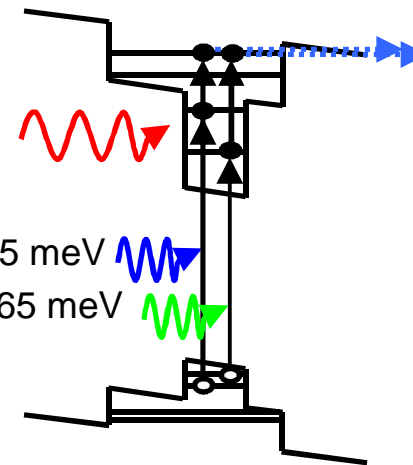
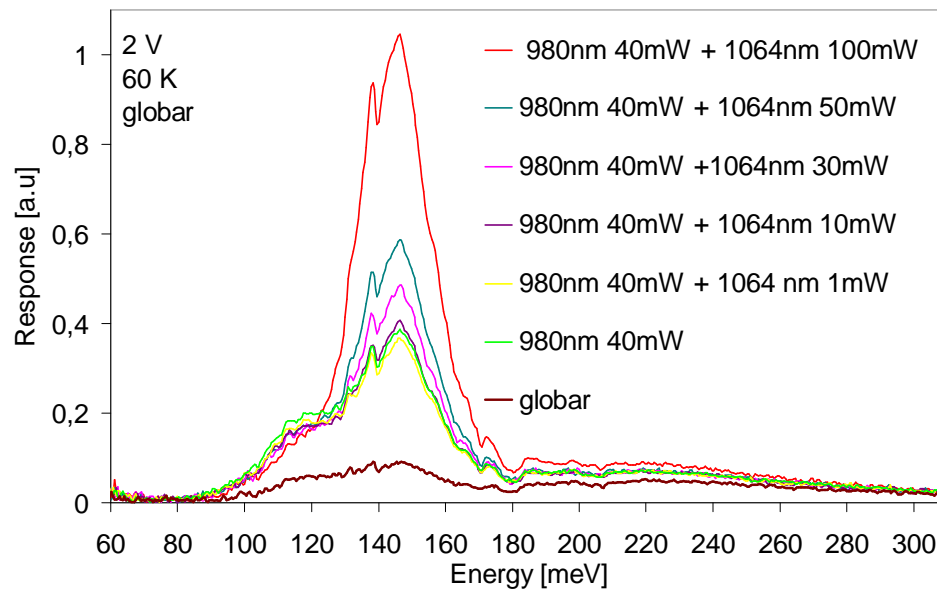
MWIR-LWIR



# Optical pumping to predict the performance



The performance was investigated by filling of the energy levels with dual source optical pumping.



**10 times higher  
responsivity**

→ **≈ 150 mA/W**

# Summary

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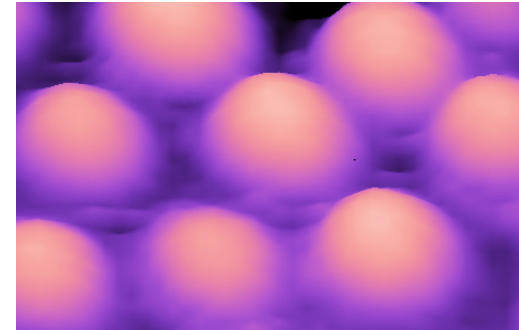


- Optical pumping used as artificial doping
- Low temperature photocurrent peak identified
  - originates from QD excited state
- Responsivity predicted to be at least 10 times higher than in the undoped case  $\approx 150$  mA/W

## ***Further reading:***

- \* Appl. Phys. Lett. **93**, 103501 (2008)
- \* *Optical pumping as artificial doping in quantum dots-in-a-well infrared photodetectors* – soon published in Appl. Phys. Lett. 94 ... (2009)

# Thank you!



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